An Evaluation of Hazard Surveillance and Flight Control with Displays of Varying Magnitudes

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Presentation Outline

- Explore why display size is an issue that should be examined
- Means of size manipulation
  - Physical size
  - Axis compression
- Examining size effects in a multi-task, integrated hazard display
  - Distance estimation
    - Flight control
    - Hazard risk assessment and route selection
  - Hazard surveillance and monitoring
  - Hazard search

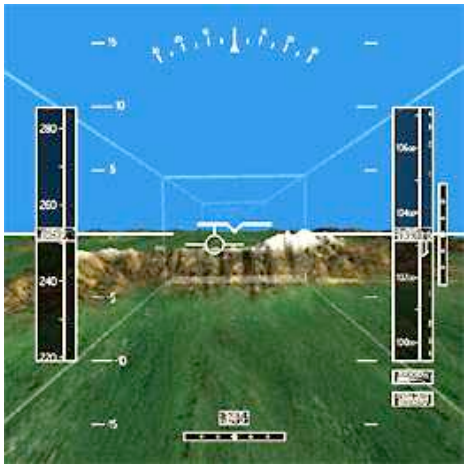
The Issue of Size

- Cockpit "real estate" is sparse, leading to display minification

-- OR --

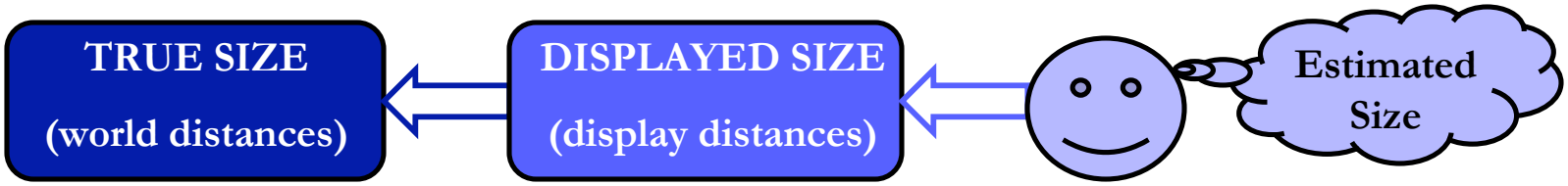
- Recent technological advances allow for larger displays – synthetic representation of cockpit view

- Changes to size may impact tasks that these displays are designed to support – important to explore this issue



Size Manipulation

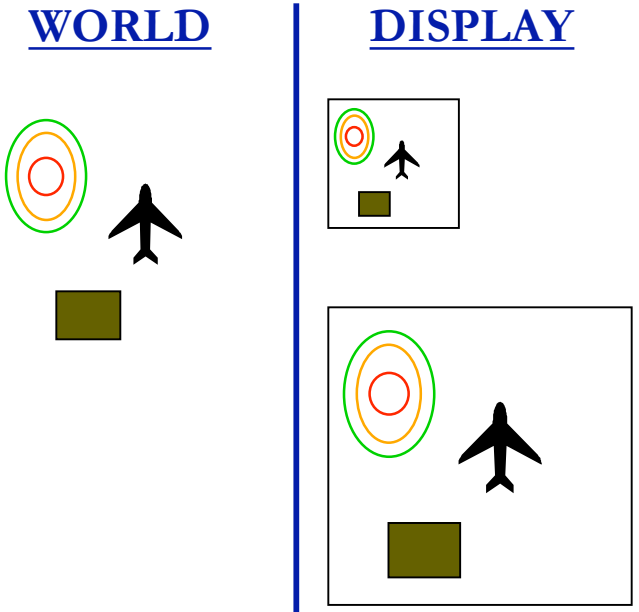
- Most important distances are *world distances*
  - How many miles until I reach the waypoint?
  - How far am I from my target heading in degrees?
- *Display distances* are used to represent world distances
  - Centimeters, degrees of visual angle, pixels



Display distances : world distances

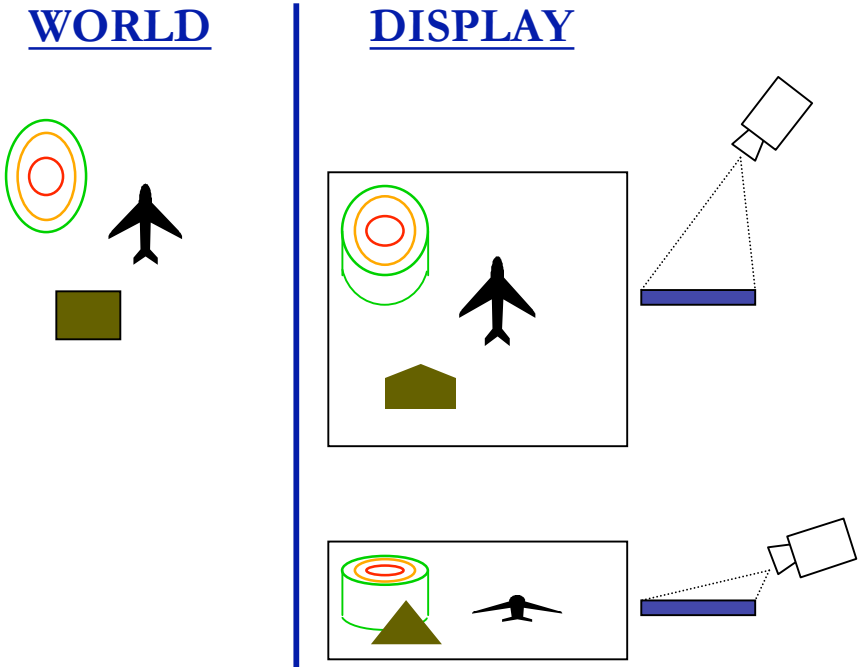
Means of Size Manipulation

- Physical size
  - World is presented on small or large display



Means of Size Manipulation

- Physical size
  - World is presented on small or large display
- Axis compression
  - Axis (or axes) along line of sight is compressed



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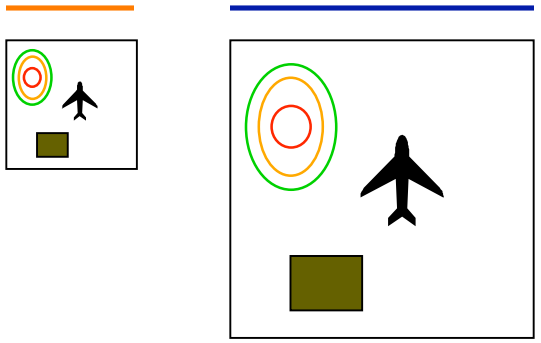
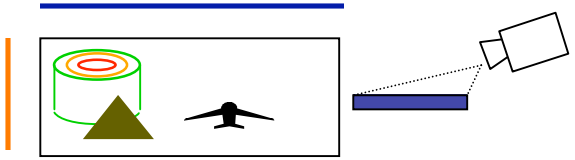


- Axis compression
  - Axis (or axes) along line of sight is compressed

- **Regardless of means of manipulation, display units to world units ratio is equal**



The Integrated Hazard Display

Goal: evaluate how size (physical size, axis compression) of an integrated hazard display can influence performance

Integrated Hazard Display

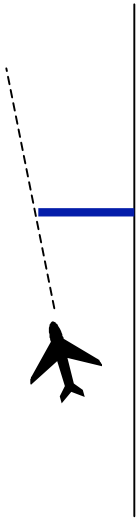
- Presents terrain, traffic, and weather information in single panel
- Eases surveillance demands
- Integrated view of airspace ⇒ integrated mental model
- Supports surveillance, tracking, risk assessment, flight planning

Provide an overarching examination of the effects of size on tasks simultaneously supported in a single panel display

Distance Estimation

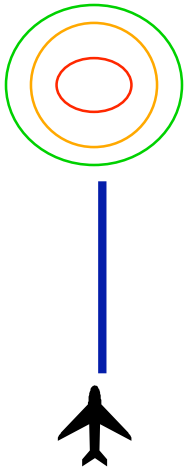
TRACKING

How far am I from my flight path?



ROUTE PLANNING

How far am I from the weather system or mountain and therefore when do I need to divert?



Distance Estimation - Accessibility

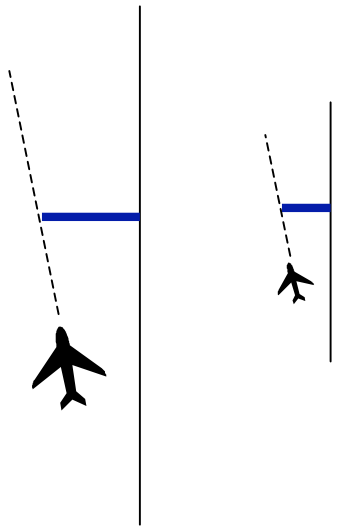
- Estimating world distances requires explicit or implicit calculation

  World Distance = Display Distance * Scale

- Display distances are salient, *accessible* (Kahneman, 2004)

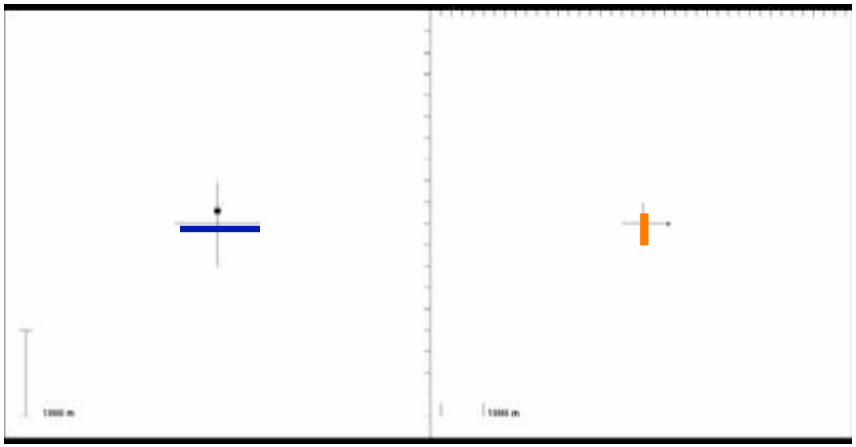
How do variations in the **display distance to world distance ratio** affect or **contaminate** these distance judgments and the subsequent tasks of flight control and decision making?

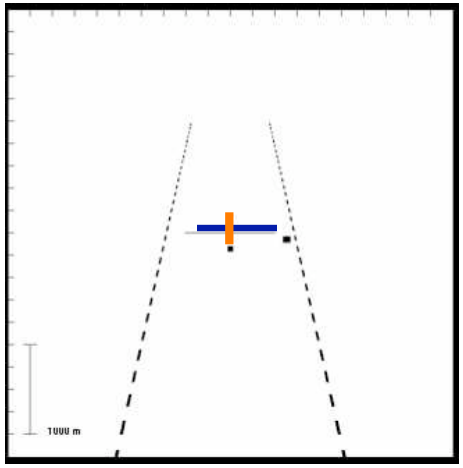
Are these errors perceived as equal, or is the error in the large display perceived as larger?



Size and Flight Control

- *Purpose*: examine presence of size contamination on distance (deviation estimates) in flight control
- *Task*: keep the "aircraft" in the designated target zone – 500 m from center (+)
- *Displays and Manipulations:*
  - 2D: physical size
  - 3D: axis compression
- Ratio of small to large was equal across dimensionality

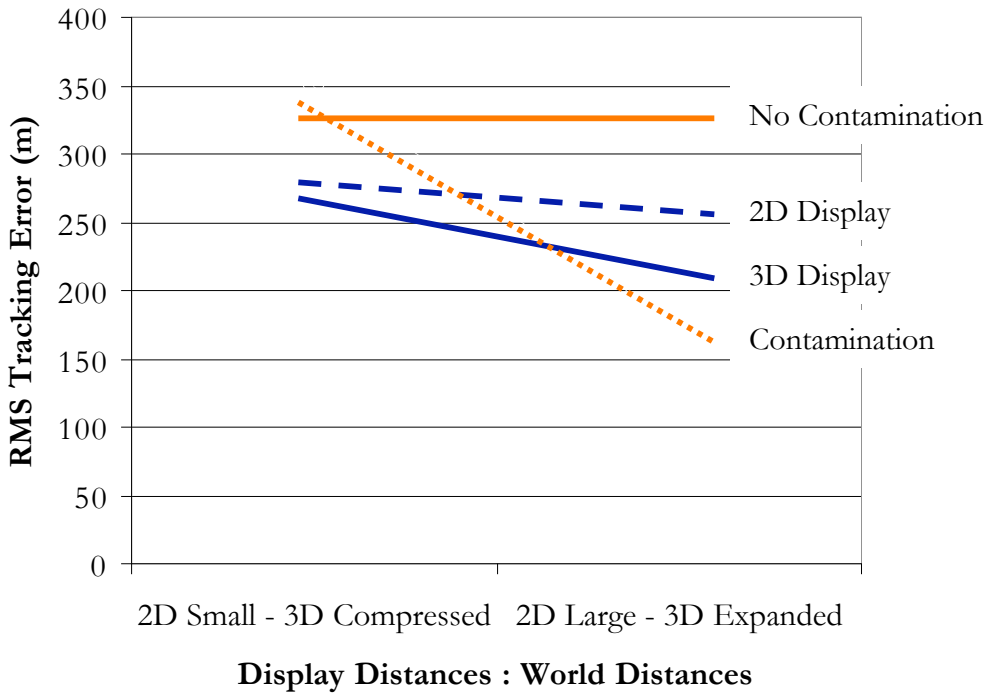




See Muthard & Wickens (2004) HFES Proceedings

Size and Flight Control

- Larger error with small display – evidence of *size contamination*
- Size contamination was greater for the 3D display than for the 2D, even though ratio of sizes was equal
- Suggests underlying cognitive component to size effects, rather than purely perceptual component



Size and Flight Control - Conclusions

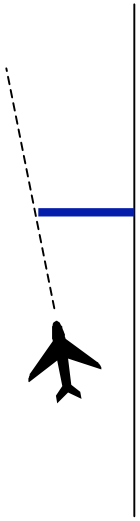
- Analyses show that tracking with minified display leads to increased error
- Evidence to suggest that the displayed size of a deviation (i.e., the ratio of display units to world units, or scale) can influence the *perceived* size of the deviation
- Because world distance is difficult to calculate (World Distance = Display Distance * Scale), and because display distance is so *accessible*, pilots' estimation of world distance becomes contaminated by display distance, at least to a small degree
- Contamination was limited in its magnitude, however, and was less than that predicted if pilots relied *only* on display distance information

- What happens when a pilot must make *several* distance judgments in a short period of time?

Distance Estimation

TRACKING

How far am I from my flight path?



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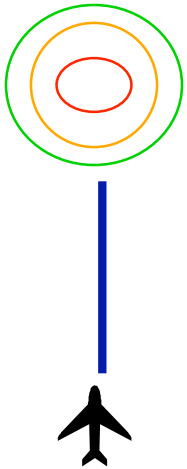
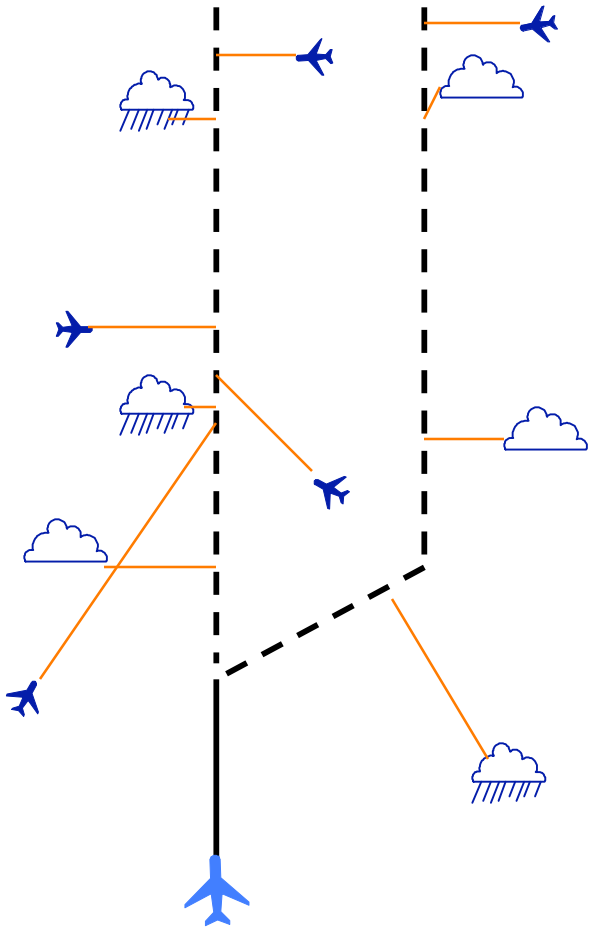
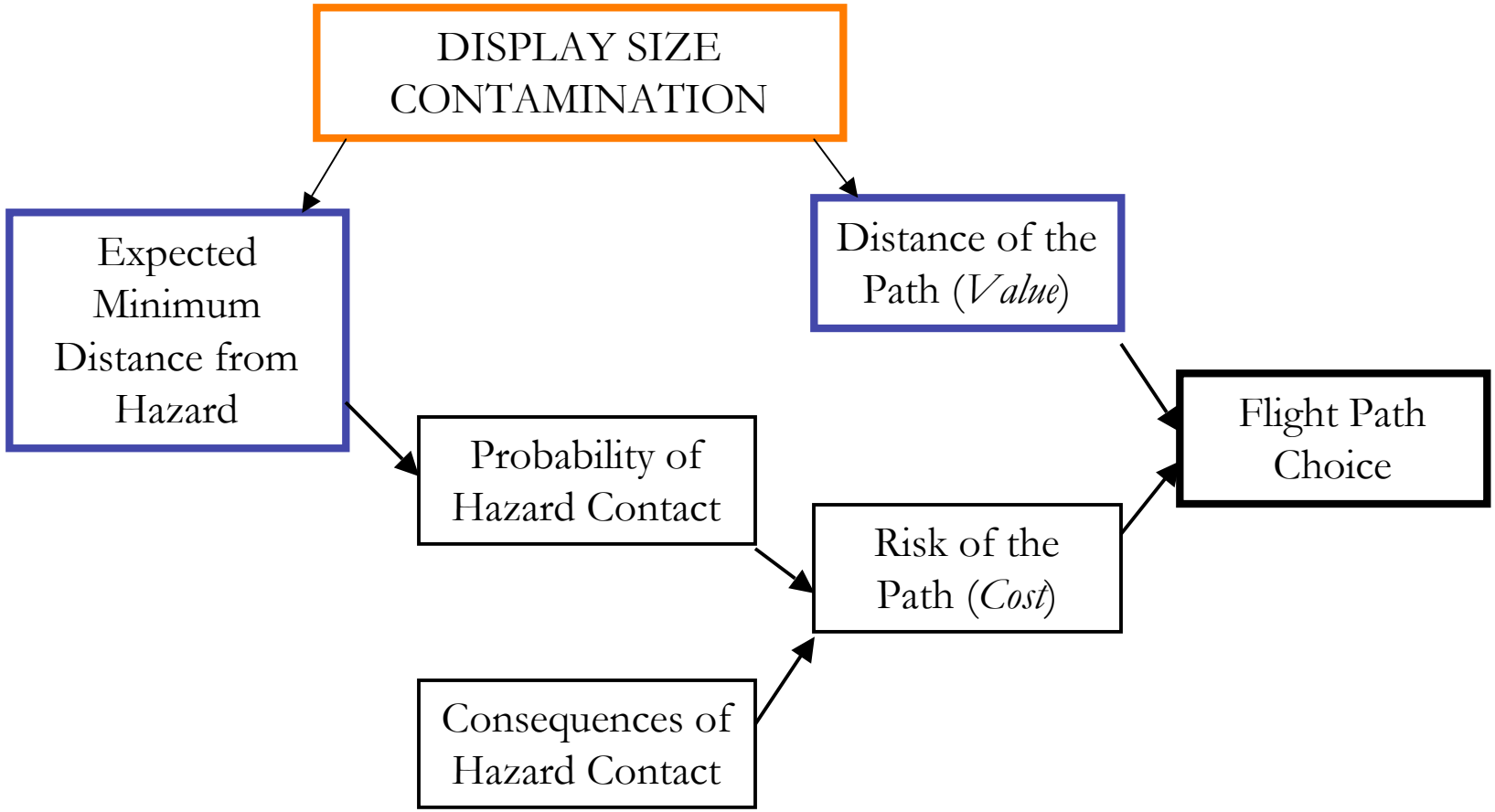


Risk Assessment and En-Route Planning

- Flight path selection depends upon relative risk assessment
- Risk = distance at projected closest point from ownship to hazard
- In fact, pilots depend most heavily on distance information (as opposed to speed) when predicting a conflict (Law et al., 1993; Xu and Wickens, 2004)
- Several judgments of distance must be made in a short period of time, which is cognitively difficult
- Thus, pilots might make quick, global judgments of distance, which can be contaminated by size
- No data yet, but we can hypothesize

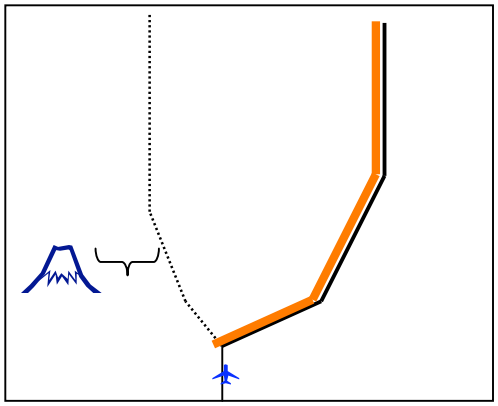


Size and Risk Assessment



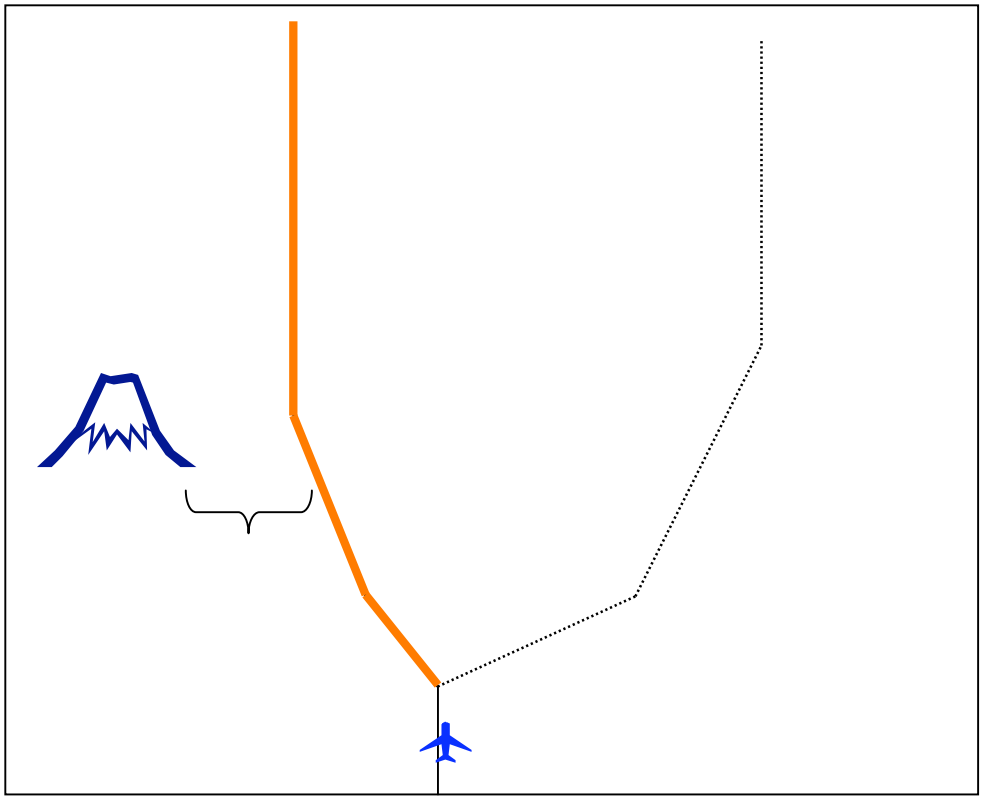
Size and En-Route Planning

PREFERENCE REVERSAL



Distance from hazard appears to be smaller

Length of safer route appears to be shorter



Distance from hazard appears to be larger

Safer route appears to be longer (less efficient)

Distance Estimation - Conclusion

- Deviations presented in a larger display scale were corrected with greater urgency, even though they represented world distances of the same magnitude

- Size contamination of path deviation estimates suggests that estimates of distance from ownship to environmental hazards might also be contaminated by shifts in display size

- These contaminated estimates of distance may cause shifts in enroute path selection, leading to less efficient route choices with small displays, but riskier route choices with large displays

The Integrated Hazard Display

Integrated Hazard Display

- Presents terrain, traffic, and weather information in single panel
- Eases surveillance demands
- Integrated view of airspace ⇒ integrated mental model
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Surveillance

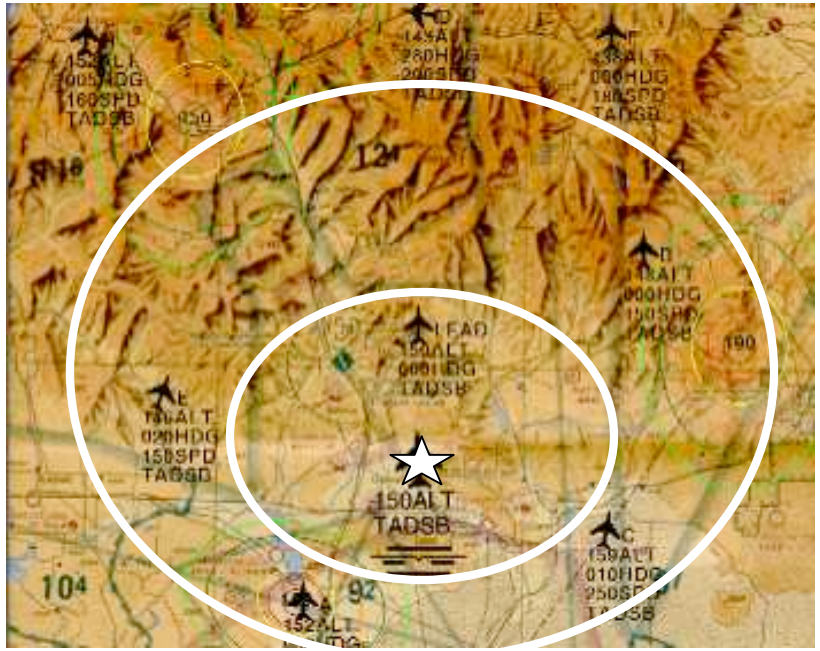
- In aviation, hazard surveillance involves monitoring dynamic hazards (traffic and weather systems) for their progression through the airspace

- Generally, involves detection of *changes* in the directional heading or altitude of these hazards

- Research in aviation monitoring has shown that individuals usually exhibit *change blindness*, or a general difficulty with detecting changes

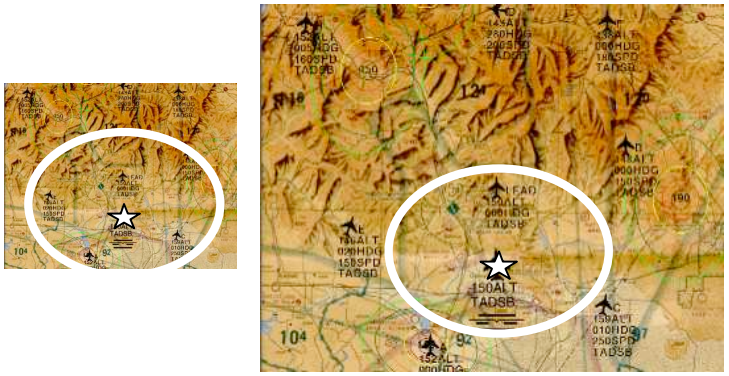
Surveillance – Change Blindness

- Performance in detecting changes also degrades with increasing distance (eccentricity) from the center of attention
- In aviation, center of attention is usually ownship
- With display enlargement, does area of attention allocation also enlarge?
- Or, does it remain of a constant angle, leaving the periphery *more* vulnerable to change blindness?

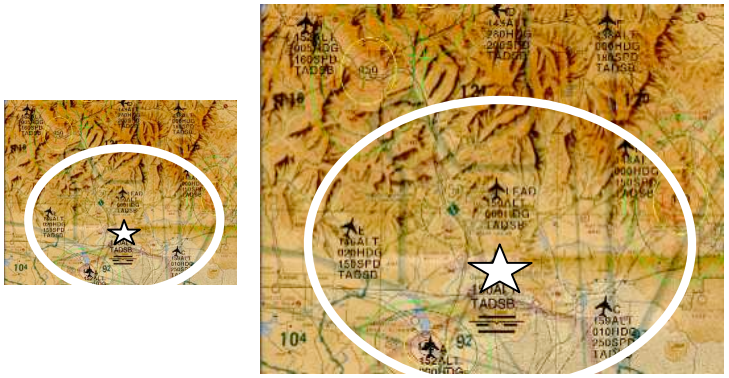


Size and Surveillance: Two Hypotheses

- Effort Conservation
  - Observers do not account for differences in display size
  - Conserve effort with enlargement by scanning the same area
  - Results in poorer detection of events in even moderately displaced areas

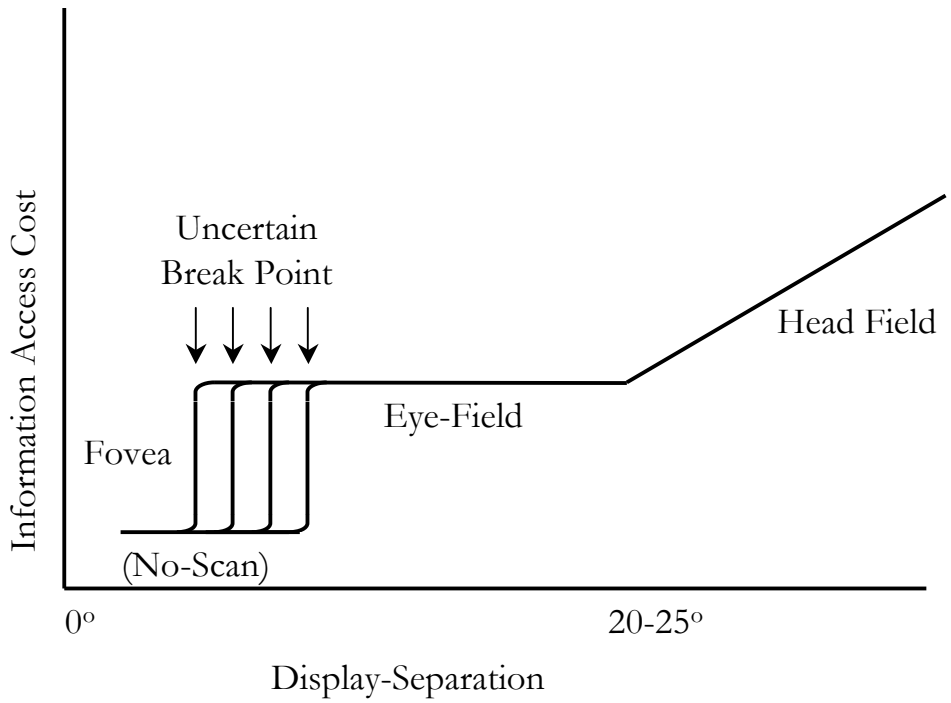


- Strategic Compensation
  - Pilots are adaptive and account for display size differences
  - Despite extra effort, pilots scan large display areas
  - Could be mediated by ongoing tasks that use up additional resources



Size and Search

- Similar effort constraints on search as with surveillance
- Size effects might be amplified if two or more objects must be compared or integrated (divided attention) during search

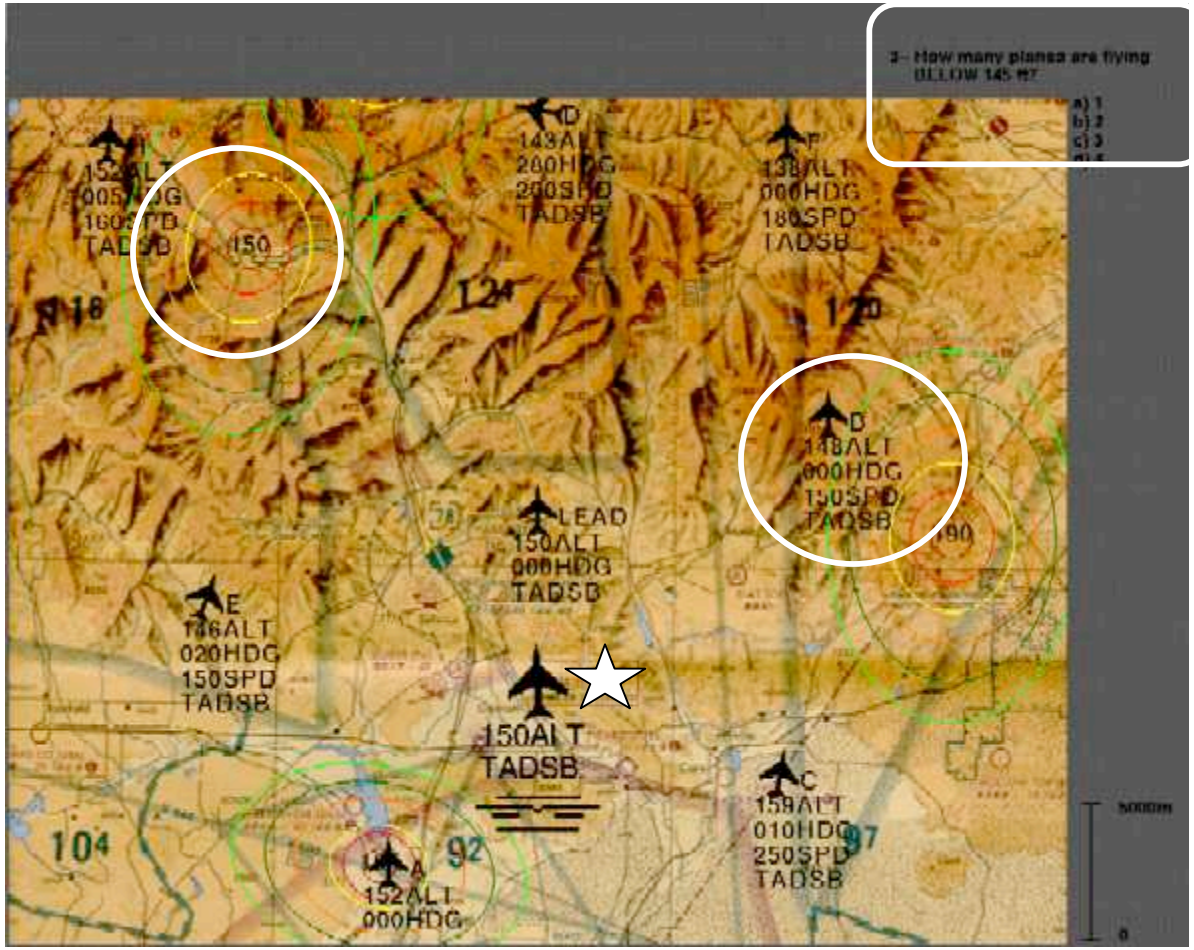


Size, Surveillance, and Search

- *Purpose*: examine influences of display size on surveillance – effort conservation or strategic compensation?
- *Task*: surveillance and search
- *Displays*
  - Small: 10° x 7°
  - Medium: 20° x 15°
  - Large: 36° x 27°

See Muthard & Wickens (2004) University of Illinois Aviation Human Factors Division Technical Report – www.aviation.uiuc.edu

Size, Surveillance, and Search



Surveillance

Detect changes to aircraft and weather heading and altitude

Search

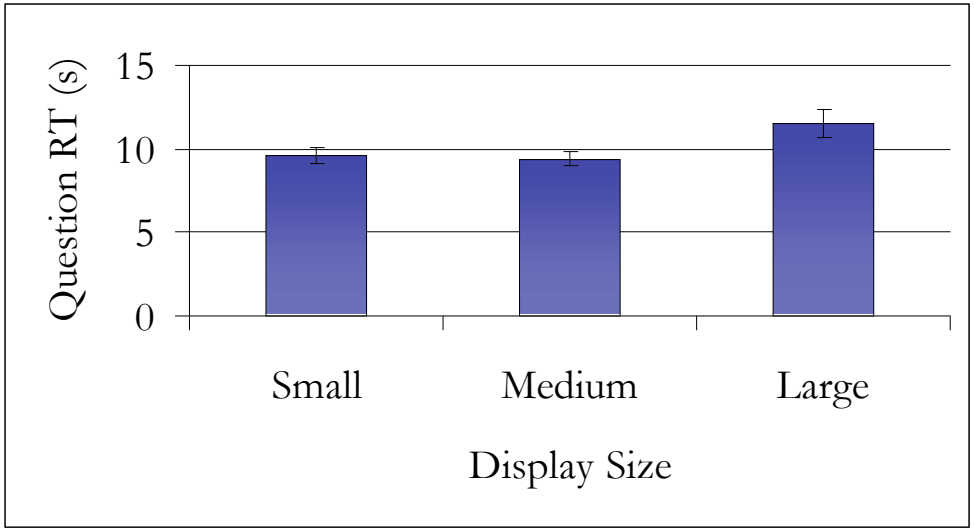
Respond to questions about hazard speed, location, or distance

Flight Control

Maintain target flight level, heading, and distance from lead aircraft – served to provide location of focused attention

Size and Search

- Consistent with effort predictions, display enlargement slowed search – effect was marginally significant
- Enlargement had no effect on accuracy



- Enlargement did not hinder accuracy or response time, even when two display elements had to be compared

Size and Surveillance

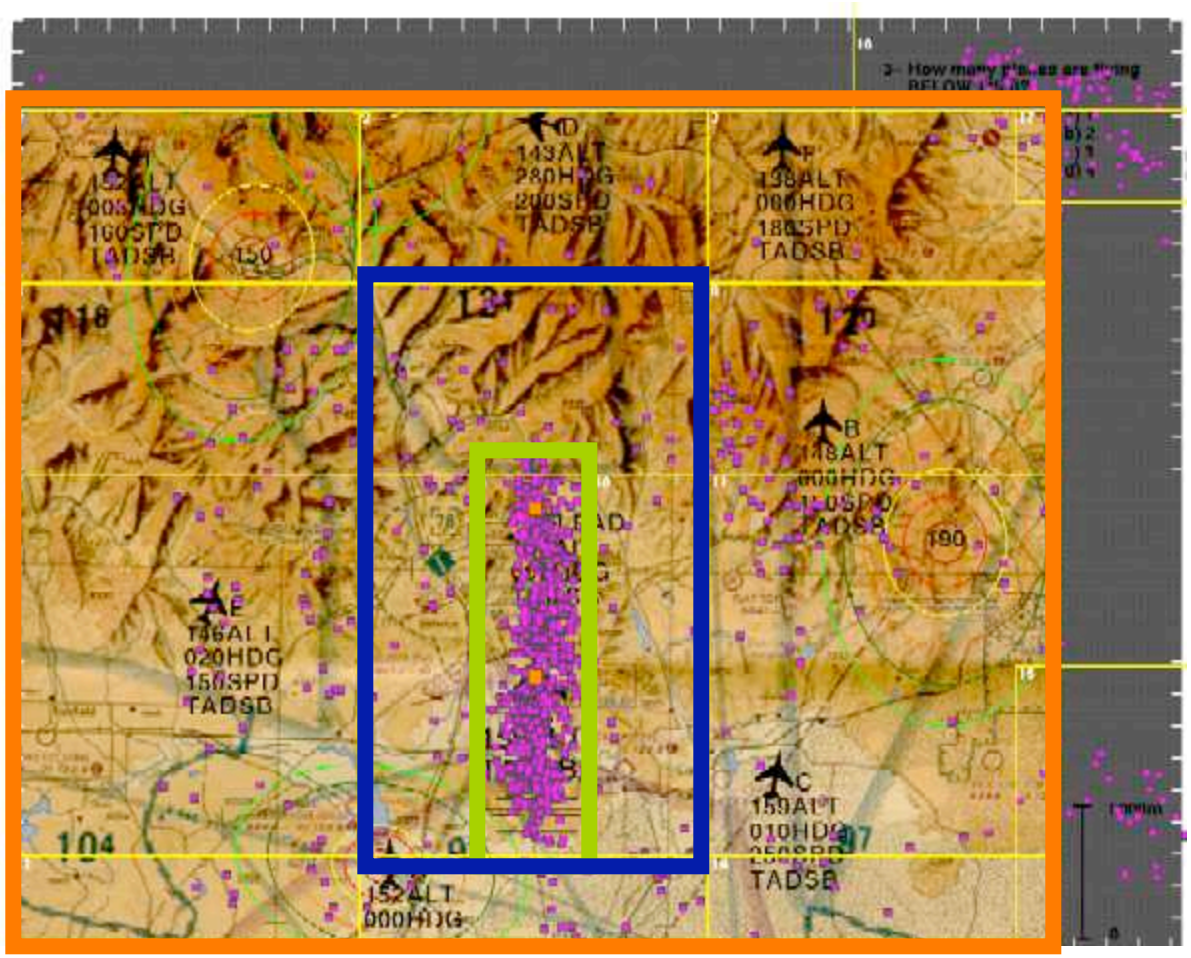
- Contrary to effort conservation predictions, change detection performance (accuracy and response time) was unaffected by display enlargement

-- BUT --

- As events occurred further from ownship, detection accuracy decreased (r = -0.45), *independent of display size*
- Thus, attention gradient (or region of attention allocation) is subjectively scaled relative to display size

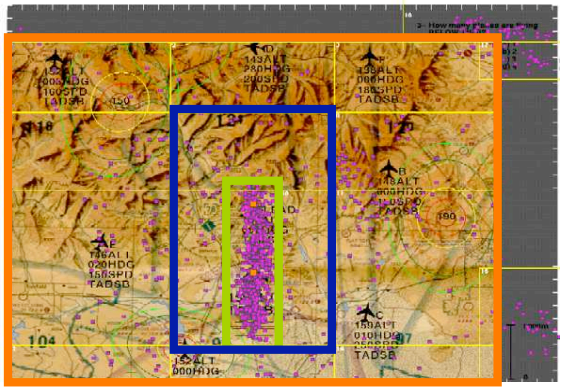
While performance data suggest equivalent surveillance across sizes, eye movement data can show surveillance behavior across display regions as a function of size.

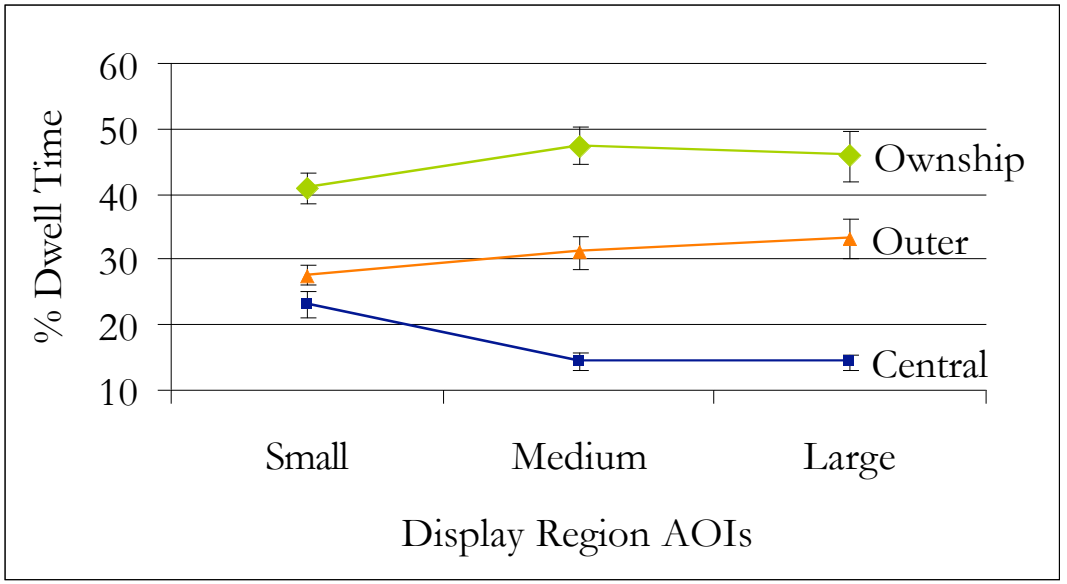
Size and Surveillance – Eye Movements



Size and Surveillance – Percent Dwell Time

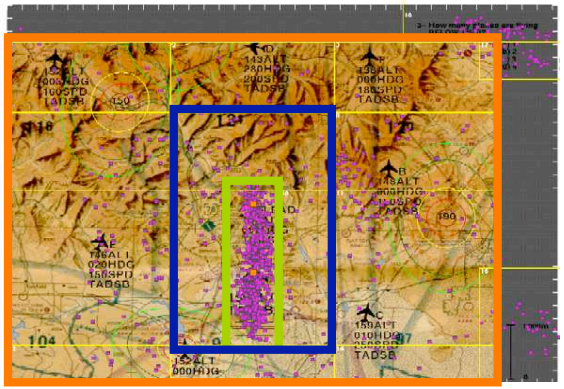
- As size was increased from small to medium
  - PDT decreased in the central region
  - PDT increased to the ownship region
  - Reflects that flight information could not be gained peripherally
- Interestingly, pilots did *not* draw attention from the outer region, despite extra effort

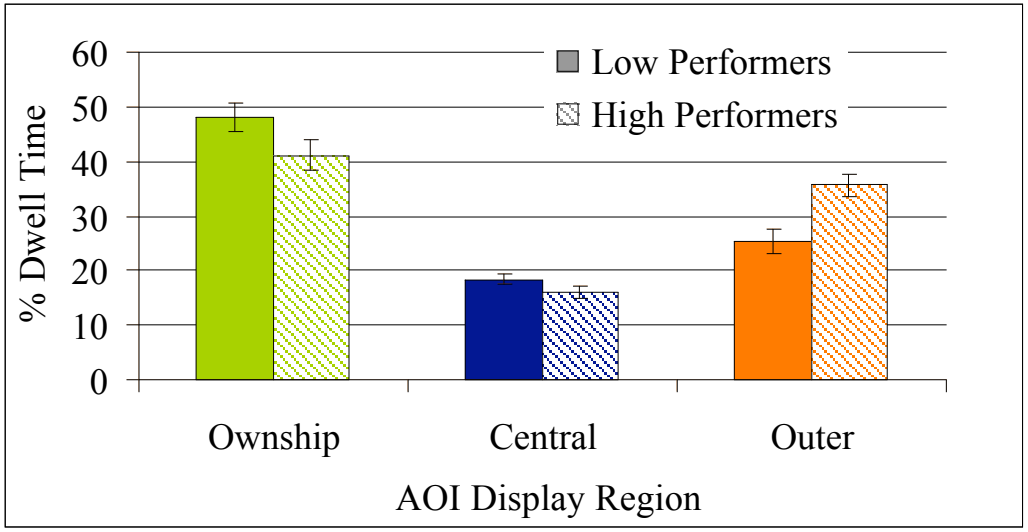




Size and Surveillance – Percent Dwell Time

- High performers allocate less attention to the ownship and central regions
- While allocating the remaining attention to the outer display region





Strategic Compensation

- Search was not influenced by size, except possibly a slight delay in response time
- Pilots detected events equally well in the small, medium, and large displays
- Pilots allocated an equal proportion of attention to the regions across display size
- Evidence from search and surveillance measures suggest that pilots are effective in *strategically compensating* for display enlargement, despite the extra effort that must be employed to do so
- Strategy seems to be effective, as higher performers spend a greater proportion of time in the outer display regions than low performers

Strategic Compensation

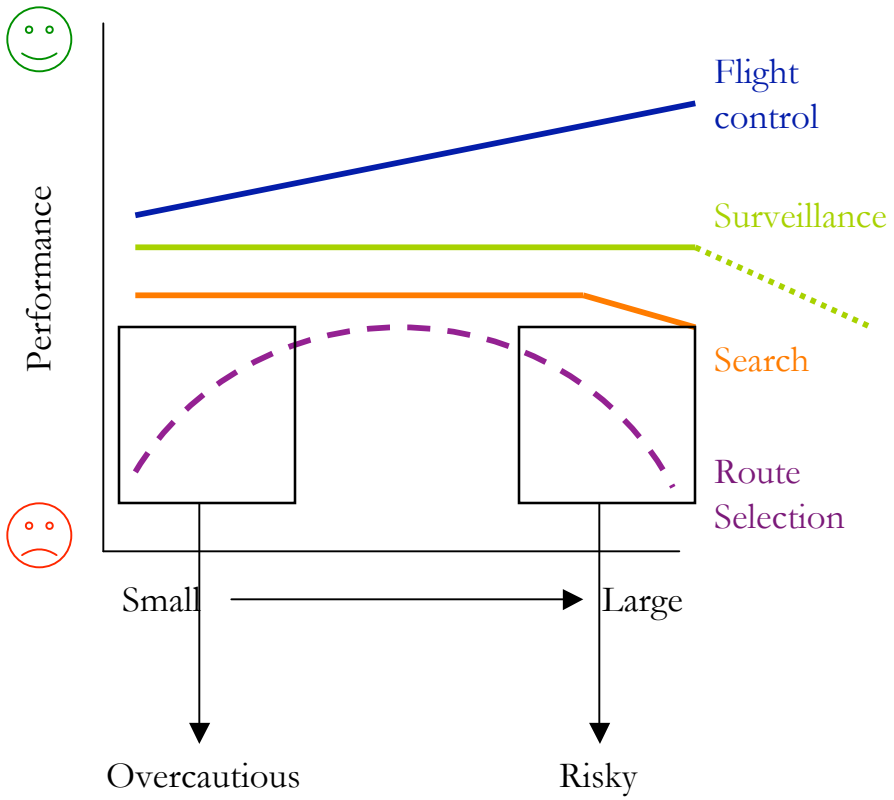
- However, surveillance performance may have been contaminated by search probes, which drove the eyes to the outer regions of the display
- To remedy this, we are currently examining the surveillance tasks, without the presence of the search probes

- While the large display subtended 36° of visual angle, head movements were not used to access information
- Thus, less effort was needed for surveillance than predicted
- However, it is unlikely that aviation displays would extend much beyond that presented here

- Increased resource demands (additional tasks, more difficult flight control) may limit the ability of pilots to maintain the strategic compensation approach

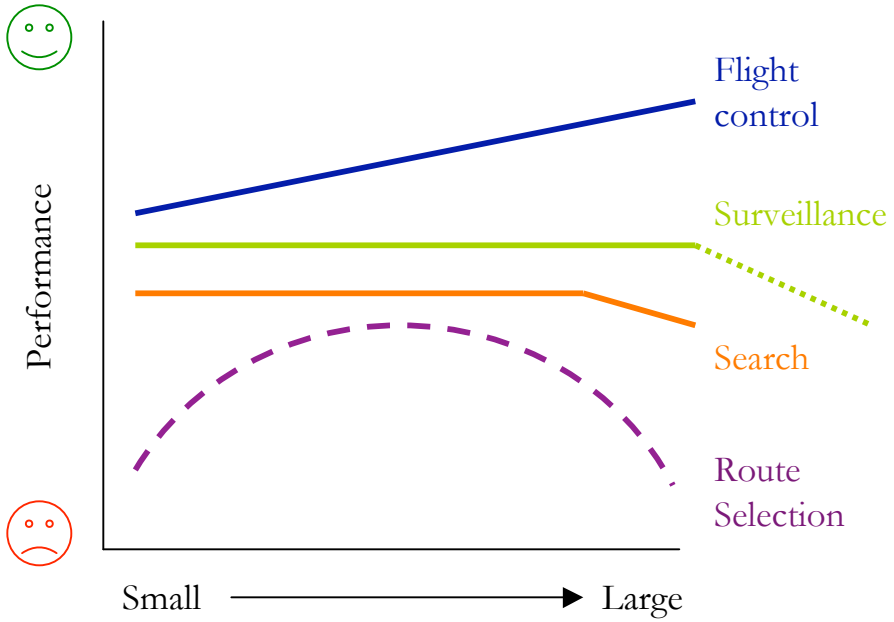
Manipulating Size in a Multi-Task Display

- Review has centered on the effects of size on multiple tasks
  - Distance estimation
  - Flight control
  - Route selection
  - Hazard Search and Surveillance



Manipulating Size in a Multi-Task Display

- With increase in multi-function, multi-mode displays, any manipulation to size must take into account
  - *All* of the tasks supported by the display
  - The performance standard (precise flying vs. hazard awareness)
- Oftentimes, a moderate, "middle of the road" approach will produce sufficient performance on most tasks



Questions?

For reprints of the papers containing the presented data,
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Thank You

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